Force and Correlation Length in Cables in Steady Flow

M.S. Triantafyllou
Massachusetts Institute of Technology (MIT), Room 5-323
Cambridge, MA 02139
phone: (617) 253-4335 fax: (617) 258-9389 e-mail: mistetri@mit.edu
Grant #: N00014-95-1-1106
http://web.mit.edu/towtank/www

LONG TERM GOALS

To obtain understanding of the basic flow-structure interaction mechanisms of marine cables subject to shear currents, so as to develop better predictive tools.

OBJECTIVES

- To map the flow behind vibrating flexible bluff bodies, using quantitative whole-field visualization, and a closed-loop force feedback apparatus, allowing the simulation of systems with complex structural impedance.
- To derive predictive models based on sectional force and flow measurements and correlation length studies.
- To corroborate the predictive models against experimental measurements on long flexible tethers.

APPROACH

We use a combined experimental/computational/theoretical approach. For experiments we use the Testing Tank Facility consisting of a larger tank (100 ft by 8 ft by 4 ft), and a smaller tank (8 ft by 2 ft by 1 ft). It is equipped with Digital Particle Image Velocimetry (DPIV) capability, allowing quantitative wake mapping, while we have constructed extensive apparatus for measuring forces on cylinders.

The Virtual Cable Testing Apparatus (VCTA), which has been developed, installed and tested extensively in the Testing Tank Facility, allows testing of cylinders in virtual free-vibration conditions (Hover, Techet & Triantafyllou 1997 and Hover, Miller & Triantafyllou 1997). It can be used to simulate conditions of complex modeled structural response coupled with real-time, experimentally measured wake dynamics. A hybrid system can be simulated, employing a closed-loop control system, which will consist of: (a) a pair of force transducers measuring the transverse forces at both ends of a cylindrical test section moving forward at constant speed; (b) a dedicated computer which uses in real-time the measured force to drive a numerical simulation of an equivalent system of desired structure; and (c) two servomotors and linear tables which impose, also in real-time, the numerically calculated motion to the cylinder section.

The apparatus results in an effective system with arbitrary structure. It has been used to simulate a mass-dashpot-spring system vibrating freely with very low effective damping (Hover, Techet & Triantafyllou 1998), as well as complex systems with several natural frequencies, including mode-coalescence conditions (Hover, Miller & Triantafyllou 1997).

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **Force and Correlation Length in Cables in Steady Flow**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Massachusetts Institute of Technology,Cambridge,MA,02139**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **See also ADM002252.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

WORK COMPLETED

We have mapped the dependence of the formation of hybrid modes behind long bluff cylinders, as identified in Techet et al (1998) and shown in Figure 1, on the effective shear in the flow. We have conducted visualization tests behind freely vibrating cylinders showing the effect of hybrid modes on the correlation length and the measured sectional forces.

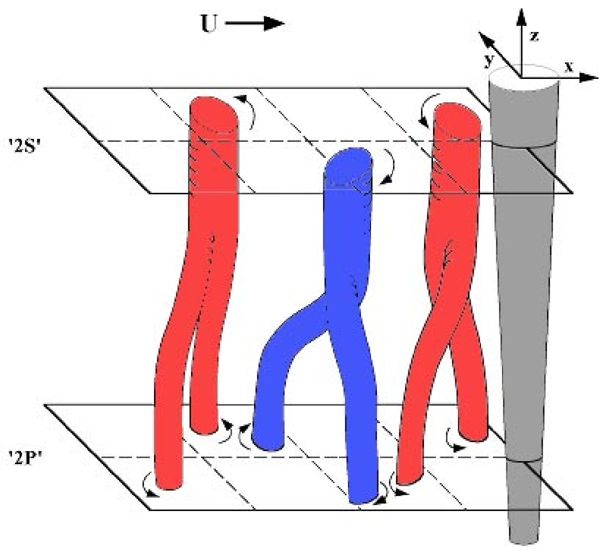

Figure 1. Sketch shows the proposed hybrid shedding mode behind a tapered oscillating cylinder with uniform free stream flow.

RESULTS

Within a narrow regime of reduced velocity containing the value V_r=5, forces measured at the two ends of a rigid vibrating cylinder appear to become uncorrelated. This is a surprising result since the cylinder still oscillates at high amplitude. We have shown conclusively since the last report that the apparent lack of correlation is due to the appearance of a hybrid mode, consisting of the stable coexistence of a “2-P” mode (two vortex pairs per cycle) over part of the length and “2-S” mode (two vortices per cycle) over the remaining length, connected through a vortex split. For short sections this change in mode along the length of the cylinder causes both a drop in excitation force and in hydrodynamic damping; hence, for low structural damping, high-amplitude vibrations are still possible since they depend on the ratio of the two quantities. For longer cylinders, such splits have a far more complex effect, requiring careful modeling.

IMPACT/APPLICATIONS

The identified mechanisms affecting correlation length provided needed understanding in order to properly model the flow behind vibrating bodies.

TRANSITIONS

Results from this study have been applied in the development of predictive codes for vibrating beams and cables in water.

RELATED PROJECTS

We have a working relation with related work led by Prof. Karniadakis of Brown University, and Dr. Mark Grosenbaugh of Woods Hole Oceanographic Institution. There is close cooperation with the "Free Surface Signatures of Submerged Objects" project led by Professors D. Yue and M. Triantafyllou.

PUBLICATIONS

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